Design and Development of an Egg Collecting and Sorting System equipped with an HMI for Poultry Farms

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Abstract

Poultry production is undoubtedly one of the most lucrative and popularly known agriculture business ventures in the world. The ever-increasing needs have led to the development, adaptation and utilization of new standards and technologies in developed countries. Goal number two of the United Nations Sustainable Development Goals (SDGs) focuses on the eradication of hunger. While goal number 8 focuses on economic growth, goal number 9 focus on industry and innovation. These SDGs can be contributed to by the poultry production industries by implementing an efficient and cost-effective production chain. However, developing countries like Ghana still deploy traditional method of handpicking of eggs and their separation into various sizes. To address this gap, this paper presents the design and development of an egg collecting and sorting system with an associated mobile application for poultry farms. It employs the use of sensors combined with servo and conveyor system in its operation. Sorting of the eggs is based on a weight sensing system. The overall system is equipped with a Human Machine Interface (HMI) for configuration purposes and a remote mobile application for monitoring combined with a statistical data view. The system is modelled and simulated using Solid works for optimal design before prototyping it practically. The designed mobile application runs on an Android operating system. This designed system can sort the eggs in large (56 g - 64.9 g), medium (49 g - 55.9 g) and small (42 g - 48.9 g) size ranges as per to the FAO standards. Periodically, the designed system updates the mobile application with a progress report of the performance of the system. The proposed system is affordable, portable, safe and effective for small- and large-scale production.

Keywords: HMI, Conveyer system, Eggs, Poultry

1 Introduction

The sorting and collecting of eggs in poultry production is a tedious and time-consuming activity. Care is taken, as eggs are delicate and require caution when working with them. This reduces productivity as a considerable amount of time is spent in the sorting of eggs into their various sizes before marketing. Farmers, on the other hand, invest a significant amount of money in the sorting process as many labourers are required in the collecting and sorting process. The profit generated after sales is disheartening. Ghana poultry sector for nearly a decade has contracted an intense competition from the import of poultry meat decreasing the profitability of egg production (Anon., 2020). Automating this process will help increase profit and improve productivity as well.

Agribusiness is a field rising with technological advancements in recent times. Researchers are coming up with innovative ideas and smart machinery to automate processes and increase production on a large scale. A field survey conducted in the western sector of the Greater Accra Region of Ghana to understand the challenges faced by poultry farmers, proved that poultry are only in demand during festive seasons hence, it is better to focus on the production of eggs to gain some profit than engaging in poultry production (Agyei-Henaku, 2016). Based on this survey, the incorporation of a design to aid in the easier sorting and collection of eggs will help increase productivity and generate more revenue for farmers. Hence this research seeks to design a collecting and sorting system incorporated with an HMI to aid in the sorting and collection of eggs in poultry farmers.

1.1 Related Works

Mitchell *et al*. (2013) invented an egg packaging system which allows eggs to assume a particular orientation within the package. The subject of the project was on systems and methods for processing eggs. The research viewed the various processes eggs go through before getting to the consuming public; that is the washing, candling, weighing, grading, and packaging into cartons, creates and various commercial containers. The work output of some of these systems is high. Some systems can process as many as one million eggs per day and with some also processing 20,000 eggs per hour. Eggs are perishable items susceptible to spoilage hence needs to be marked with its expiration dates on it. Various methods were introduced however are not productive, especially the use of vegetable water-soluble dyes in marking. Such markings could fade off or enter into the interior the egg. The date of expiring will not be noticed thus, not an effective method. This research sought to curb that problem with the laser marking where the date of expiry of an egg could easily be determined.

Ibrahim *et al*. (2012) researched into Eggs Grade Classification and Dirt Inspection Using Image Processing Techniques and their benefits. The paper also highlighted the importance of egg grading. Internal and external qualities of an egg play a significant role in the grading. The experiment was conducted with the aid of a webcam. The system was able to classify the sampled eggs into their respective grades with a performance accuracy of 80% to 90%. One main challenge associated with the research was low quality of captured image.

Ashitey (2017) accounted for the annual Ghana Poultry Report in the year 2017. The article estimated that Ghana's broiler meat production would increase to about 35,000 tons which would lead to a supply of less than 25% of demand. From the statistics, imports of poultry products were expected to increase due to insufficient domestic supply and growing demand. The report concluded clearly that, the high demand for the poultry product was as a result of fast-food operators, quick service restaurants (QSR) and household consumers preferring to purchase the Brazilian chicken due to its large size.

Quilloy *et al*. (2018) focused on the usage of machine vision and mechatronics in the separation of eggs. The machine developed comprised of a feeding, computing and a sorting unit. ECGSoTiC, a machine vision software was used in the sorting process. A test for similarity of readings indicated that the developed machine is capable of yielding consistent results. Results on the dynamic test for about 100 egg sample resulted in a 91% accuracy. Based on the metric of evaluation, the mean squared error, it was realised that no large errors were obtained indicating how well the machine performed.

Alikhanov *et al*. (2019) in their article, focused on developing an automatic system for egg soring with the help of an indirect weight and shape assessment using computer vision. In automating the sorting process, the system is equipped with a programmable controller and a frequency-controlled electric drive. This allows control of the actuators and the speed of the conveyors. This innovation allows the system to be more flexible and easy to adjust when changing production requirements. Some parameters considered were the perimeter and area of the egg, shape index and shape factor of the eggs and the minor and major of the egg. The sorting accuracy of the proposed system was evaluated using 2 and 3 eggs per second. An accuracy of 94.6% and 90.3% were obtained respectively.

1.2 Proposed Solution

Eggs upon being laid will be gently role unto a conveyor belt (battery cage system). These eggs will run slowly underneath the hen-coop, driven by a dc motor from one end to the sorting chamber where the sorting process begins.

The weight of the eggs is determined by the weight sensor. After being weighed, with the help of a servomechanism, eggs are grouped into various groups of weights (ranging from 28 g to 55 g) to the point of collection. An HMI is incorporated to aid in calibration and troubleshooting, also visually displaying to the user the operation pattern of the machine. The HMI also keeps records and provides statistical analysis. Fig. 1 shows the pictorial demonstration of the system.

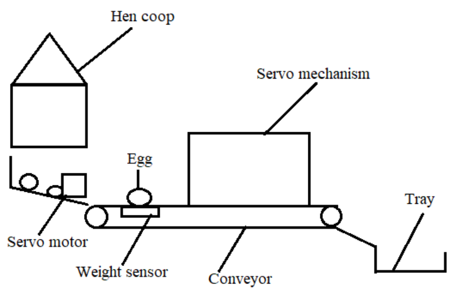

Fig. 1 Pictorial View of Egg Conveyor and Sorting System

2 Materials and Methods Used

2.1 Procedure of Proposed Design

The process begins when the presence of an egg is detected by the load cell. Its exact weight is being identified and quickly communicated to the microcontroller. Based on the egg weight, the right servo mechanism is signalled, and with the help of the smooth driven conveyor belt, channelled to the appropriate tray. Eggs found outside the selected egg ranges are channelled to a designated tray for further inspection as shown in Fig. 2.

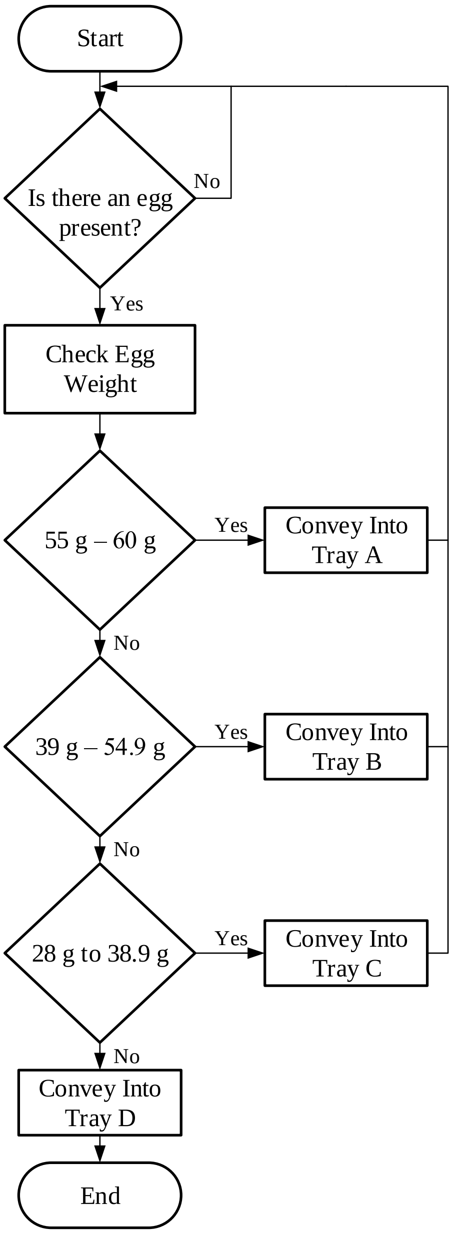

Fig. 2 Flow Chart of Design Concept

2.2 Design Concept

The egg collection and sorting model is made up of; an AT mega 328p microcontroller, 12 V 40 RPM DC geared motor, servo motors, LEDs, a buzzer, a load cell with its converter and the HMI. Figure 3 summarises the components and chain of operation.

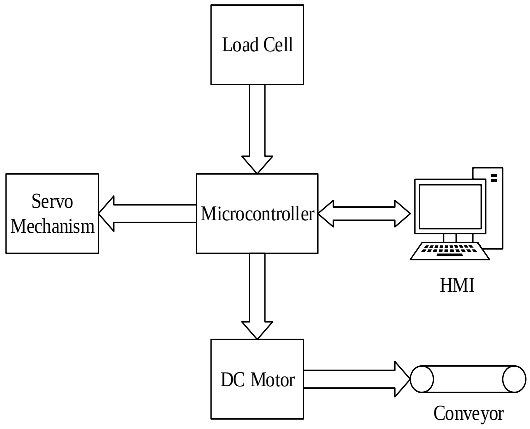

Fig. 3 Block Diagram of Design Concept

The egg collection and sorting machine is designed with both electrical and non-electrical parts. The non-electrical part comprises of wood, PVC pipes, cushion, aluminium plate, screws, nails, a junction box for housing the electrical components, glue and leather material. While the electrical components consist of servo motors, relay, DC geared motor, Arduino nano, toggle switches, load cell, hx711 Analogue to Digital Converter (ADC), buzzer, Light Emitting Diode (LED), printed circuit board, 5 Volts battery and 12 Volts dc adapter.

2.2.1 Reasons for Component Selection

The reason for the selection of these components are explained below.

2.2.2 Atmega 328 Microcontroller

The Atmega 328 microcontroller was chosen for this design for its easy programmable nature, enough input and output pins (20) and its compatibility with an Arduino Nano board.

2.2.3 Servo Motors

Servo motors possess the following features: power supply voltage and current ratings ranging from 4 V – 6 V and 100 mA – 1 A respectively, a torque of 1.6 kg/cm and a weight range between 15 g and 200 g. These qualities make them suitable for integration in the design.

2.2.4 DC Geared Motor

In the selection of the DC geared motor, the required power to drive the motor and the load on the conveyor was calculated. Below is the mathematical formula for deducing the required power.

$$P_r = Belt\ pull \times Belt\ speed \tag{1}$$

$$Belt\ pull = T_W + (B_w \times \mu) \tag{2}$$

Where, P_r = Required Power

T_w =Total weight of package (egg)

B_w = Belt Weight

μ = Coefficient of friction

2.2.5 Hx711 ADC Converter

The scale factor for the load cell used in this research is calculated below:

$$Scale = \frac{output \times ADC \times excitation}{cell\ range \times VCC} \quad (3)$$

where,
output = the output rating of the load cell (V)
ADC range = the range of values of ADC
Cell range = maximum rating for load cell
VCC = system voltage for the amplifier
Fig. 4 presents a pictorial circuit diagram of the design.

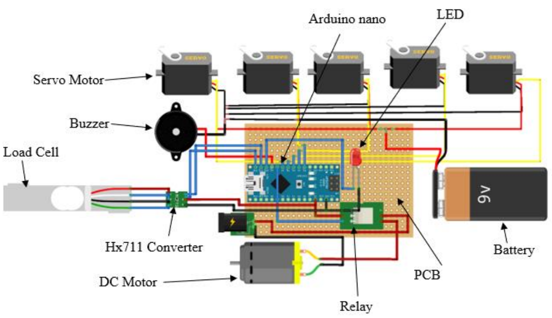

Fig. 4 Pictorial Circuit Diagram of Proposed Design

2.3 Materials Used in the Circuit Design

In the implementation of the proposed design materials such as packing plywood, PVC pipes, aluminum, cushions, leather material, bearings, a junction box, nails and screws were used.

2.3.1 Metallic Materials

The servo arm of the machine is made of aluminium sheet of thickness 1 mm. The 1 mm is to provide sufficient rigidity and also mechanical support to the arm. The reason for the selection of a 1 mm sheet is for less weight for easy rotation of the servo arm.

2.3.2 Plastic Materials

The pathway sliders of the machine are made of Polyvinyl Chloride (PVC) pipe with a thickness of 4 mm. This allows for the easy and smooth transition of eggs into the collection trays.

2.3.3 Wooden Materials

The entire body of the machine is made of 6 mm packing plywood. This is because compared to the regular 6 mm plywood, the packing plywood is more durable and can firmly hold on to adhesives and nails, notwithstanding its rigidity and strength.

2.3.4 Leather Material

Leather material was used in covering the entire body of the machine to provide it with a soft smooth surface.

2.3.5 Arduino Nano

The Arduino Nano microcontroller serves as the brain or control board of the egg sorting and conveying machine. It runs on the AT mega 328p processor, which reads data from its input pins and sends corresponding signals to the output pins. These signals then drive the servo motors and also starts the dc motor. The input pins receive data from the HMI via serial communication. Some input commands also come from the control switches.

Features such as memory size, i.e. (32 kilobytes), operational speed, size, response time, price, simple connectivity and availability of more input and output pins led to the selection of the Arduino Nano microcontroller.

2.3.6 DC Worm Drive Motor

DC worm drive motor is a class of electrical rotary machine which converts electrical current to mechanical energy. Its principle of operation is based on the forces produced by magnetic fields. The reason for the selection of this type of motor is its low speed but capable of extremely high torque; also they offer a brake features by nature of design meaning the load on the motor cannot turn the motor even when there is no power applied. Another useful feature is they offer a right angle (or even left angle) gearbox for practical mounting in tight spaces.

2.4 Final Solid Works Design

The final design was modelled using SolidWorks 3D. Figure 5 shows the third angle projection and dimension of the designed prototype. The software was used in designing the various parts of the machine as shown in Fig. 6. These parts were then assembled to form the egg collection and sorting machine.

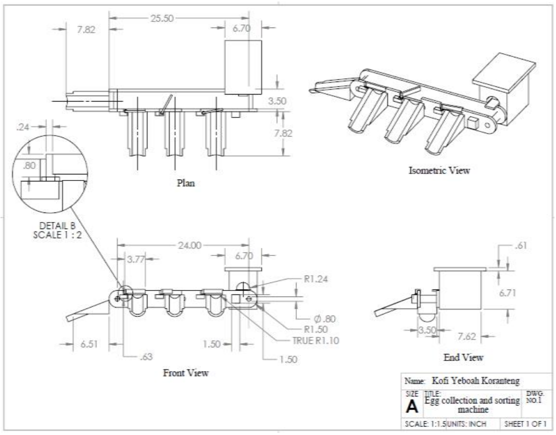

Fig. 5 Third Angle of Projection and Dimensions of the Designed Model

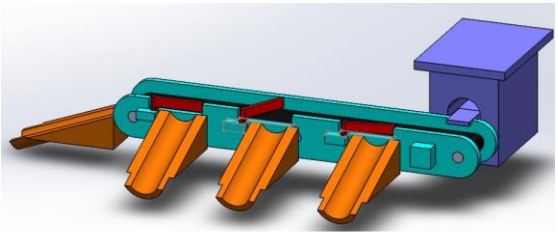

Fig. 6 3D Design Model of the Egg Collection and Sorting Machine

3. Results and Discussions

The designed system was user friendly, easy to operate, affordable and made with locally available materials. The cost of building the proposed design for the specified dimensions was GHC 583.55 (At a Dollar to cedi rate of $ 1.00 to GHC 5.76; 21 February, 2020). The finally designed machine is shown in Fig. 7.

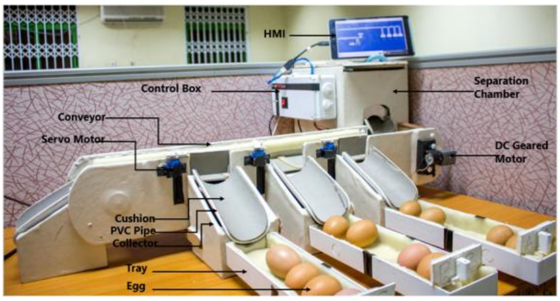

Fig. 7 Egg Collection and Sorting Machine Operation

There are two operating modes of the machine. Operation with the HMI and operation without the HMI.

3.1.1 Operating with HMI

In this operation mode, the machine commences operation when connected to the HMI. Records of activities that take place in the machine are saved and a graph constructed to provide a summarised conclusion for viewers, as shown in Fig. 8, and Fig. 9 respectively. This helps the farmer keep track of eggs coming from the farm, synched with the HMI is a mobile application which provides an exaptational user experience from anywhere with internet access. Runtime of the machine is also recorded aiding in troubleshooting and easier diagnosis in cases where the machines fail to operate.

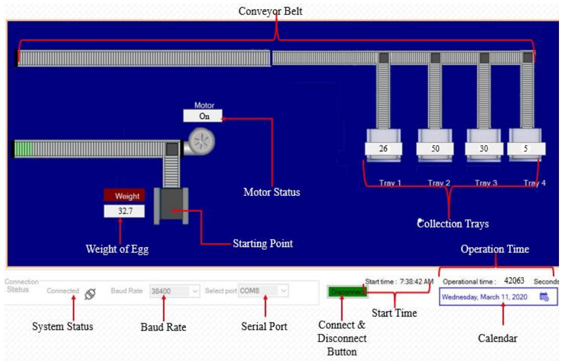

Fig. 8 The Human Machine Interface

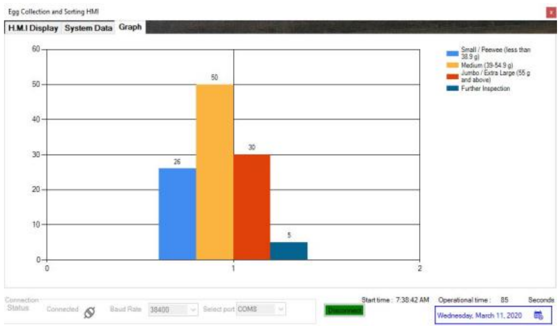

Fig. 9 A Graph of Egg Records

3.1.2 Mobile Application

Upon launching the application, a user account with the new user details is required of the new user as shown in Fig. 10.

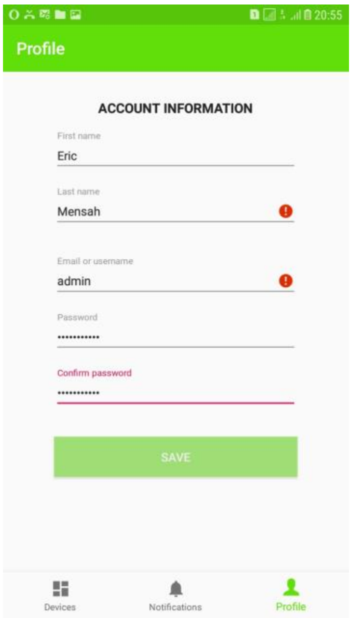

Fig. 10 Screenshot of User Account Information

To be able to add or identify an egg collecting and sorting machine, the unique QR code identifies on the body of the machine is scanned. This provides the application with all necessary information of the machine. This can be seen in Fig.11.

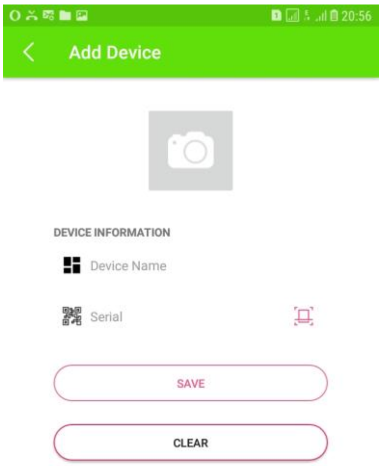

Fig. 11 Screenshot of Device Connectivity

Once successful connectivity is achieved, all necessary information from the egg collecting and sorting machine and its HMI is made available to the mobile application as shown in Fig. 12.

Fig. 12 Screenshot of Results from HMI

3.1.3 Operating Without HMI

In this operating mode, the machine begins operations until turned off. However, no records are kept during operation.

4 Observation, Conclusions and Recommendation

4.1 Observation

The machine successfully sorts eggs into the three groups based on their weights. Eggs out of the specified weight ranges was directed to another chamber for further inspection.

4.2 Conclusions

In this study the sorting process of the egg was done with the help of a weight sensor. This system as compared to the other existing system is better as its energy cautious and flexible to use by the farmer on field.

The porotype machine was made from locally sourced materials. This initiative was aimed at reducing the cost in production as well as increase the usage of local products. It was also realised that the machine was relatively cheaper as compared to the conventional ones.

The total time taken in is 20 seconds; therefore a total of 1,440 eggs (48 crates can be classified within 8 hours).

The system however is equipped with an HMI allowing for proper visualisation on the machine during operation and diagnosis in the event of a breakdown. Also, a mobile application has been added to help in easy monitoring. The application gives details on the number of eggs sorted each day, the runtime of the machine as well as making troubleshooting simple to reduce breakdown time of the machine and ensure a smooth operation.

However, a limitation faced was the inability of the machine to detect cracks in the egg and separate them into a different location for easy collection. There can be further research into this aspect to cater for this defect the machine has posed.

4.3 Recommendation

Improving the technology with image recognition will help increase the efficiency of the sorting process

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